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Executive Summary

Objectives

There are two objectives for this CAD cell modeling study of the proposed lower New Bedford Harbor CAD cell: verification of CAD cell size for containment of the contaminated sediment and capping materials, and quantification of contaminant losses during dredged material placement, from consolidating exposed dredged material prior to capping and after capping, and from long-term diffusion after consolidation becomes insignificant. Containment includes not only capture and storage of the dredged material and capping materials, but also the bulk of the stripped or resuspended materials during placement and the dynamic spreading of the dredged material from the kinetic energy of the discharge during its collapse in the CAD cell.

Contaminant losses during placement includes the partitioning of contaminants to the water column from stripped or resuspended dredged material during placement, discharge of pore water from the settled dredged material by consolidation considering the entrainment of water in the dredged material during placement, diffusion of contaminants from the dredged material and through the cap, and the exchange of water in the CAD cell with the overlying water column.

Testing

Testing and characterization was conducted on five composite samples collected from DMUs 3 to 37 and 102 to 105. The sediment specimens were sampled and composited by Jacobs Field Services. Each composite was prepared to be representative of a year of dredging. Composite 1 was composed of DMUs 3 to 7, and DMUs 102 and 103. Composite 2 was composed of DMUs 8 to 15. Composite 3 was composed of DMUs 16 to 24 and DMUs 104 and 105. Composite 4 was composed of DMUs 25 to 33 and Composite 5 was composed of DMUs 34 to 37. Materials from Composites 3 through 5 are being placed in the lower harbor CAD cell. Site water was also collected by Jacobs Field Services at the locations of the two proposed CAD cells.

Sediment characterization was performed by GeoTesting Express, Katahdin Analytical Services, and laboratories at the U.S. Army Engineer Research and Development Center (ERDC).

GeoTesting Express performed for the following geotechnical analyses: Moisture Content (ASTM D 2216), Specific Gravity (ASTM D 854), Grain Size Analysis with Hydrometer (ASTM D 422), Atterberg Limits (ASTM D 4318), Flexible Wall Permeability (ASTM D 5084), and Incremental Consolidation (ASTM D 2435). ERDC analyzed the composites for moisture content (ASTM D 2216) and organic content (ASTM D 2974). Both Katahdin Analytical Services and laboratories at ERDC conducted chemical analysis of the sediment composites and harbor water samples. ERDC laboratories also conducted Sequential Batch Leaching Testing (SBLT) (ASTM Method D-4793), on the five sediment composites to determine the partitioning characteristics of PCBs and copper in the sediment. The results of the consolidation testing were used to develop void ratio-effective stress relationships and void-ratio permeability relationships for each of the five composites. The results of the SBLT were used to develop a single set of partitioning coefficients for PCBs and copper that are representative of all of the composites.

Modeling

Sizing and Filling

Several modeling tasks were conducted to analyze the CAD filling, sizing and contaminant losses. A cut and fill spreadsheet analysis was performed to determine the size of CAD cell needed to contain the proposed volume of dredged material and to estimate the lift thicknesses of the annual fills for consolidation analysis. A 650' x 650' surface footprint was selected with a side slope of 1V:6H for top 7 ft of depth and 1V:3H for the remaining 47 ft of depth.

Consolidation

The consolidation of the dredged material was analyzed using the USACE PSDDF model (Primary Consolidation, Secondary Compression and Desiccation of Dredged Fill). The PSDDF model results showed that the CAD cell size was appropriate to contain the proposed volume of dredged material, considering the entrainment of water in the dredged material, the volume of capping material, spreading of dredged material from the placement dynamics, suspended solids retention, and consolidation prior to capping. The consolidation results were analyzed to determine the predicted pore water expulsion rates for contaminant loss predictions both prior to and after capping.

The CAD sizing analysis showed that the center of the lower harbor CAD cell would be filled with 42 ft of dredged material based on its in situ density. Analysis of potential water entrainment in the dredged material during both dredging and placement through the water column yielded an estimate of bulking or entrainment that would result in placement of 52 ft of dredged material and 3 ft of capping material, a total of 55 ft of material in our cell that is 47 ft deep. However, the PSDDF model predicted that in the center section of the CAD cell, 10.3 ft of pore water would be expelled from the placed dredged material prior to capping, primarily from the 10 ft of water that was predicted to be entrained during dredging and placement through the water column (mostly at depth from the first lift placed). Therefore, the depth of fill immediately after capping is 44.7 ft, providing a freeboard of 2.3 ft. After capping, an additional 7.2 ft of pore water is predicted to be expelled in the first 10 years, 9.4 ft of pore water in the first 20 years and 10.9 ft of pore water in the first 40 years. At 40 years, the dredged material is predicted to be 94% consolidated. Based on the PSDDF model results, much of the contaminant losses would be expected to occur during placement and prior to capping.

Placement

The open water placement of dredged material in the lower harbor CAD cell was modeled using USACE STFATE (Short-Term FATE of dredged material placed in open water) model to predict the entrainment of water in the deposited dredged material, the mass of dredged material suspended in the water column, the suspended solids concentration in the water column, the settling time, and the vertical and lateral distribution of suspended solids following a barge discharge of dredged material. STFATE model runs were conducted on 500-cubic yard barge discharges at the beginning and of each dredging season to simulate the range of placement impacts for each dredging season and to estimate annual contaminant losses during placement.

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The STFATE model results show that about 3 to 4% of the fine-grained fraction of the dredged material remains in suspension about 3 to 4 hours after the barge discharge and disperses in the CAD cell water below the loaded draft of the barge, resulting in average TSS concentrations ranging from about 20 mg/L for the first lift to 150 mg/L for the third lift. In a shallow saline environment such as New Bedford Harbor and the CAD cell, the TSS concentration will typically decrease to 50 mg/L within a day and to 10 mg/L within a week.

The discharge plume collapse dynamics were modeled using the USACE SURGE to examine whether the momentum of the discharged material was sufficient to cause the dredged material to run up the side slope and out of the CAD cell. All discharges are assumed to be within the area of the level bottom, a 326-ft square, and no closer to 160 ft from the lip of the CAD cell. The dynamics were examined for all three sediment composites across the range of water depths that would exist during their placement. In all cases the discharged material is not predicted to run up the slope above a depth of about 11 ft below the lip or about 55 ft from the lip. Therefore, the CAD cell is expected to be capable of confining the dredged material during placement.

Short-Term Partitioning and Contaminant Loss

The contaminants associated with the TSS will partition with the CAD cell water. It is unlikely that the partitioning reaches equilibrium before the particles interact with subsequent discharges, flocculate and settle. The kinetics of PCB desorption in a stagnant water column is sufficiently slow that it may take weeks to reach equilibrium; however, 10 to 20% of the PCBs may desorb in the first day. The partitioning of contaminants to the CAD cell water over the large number of discharges in a dredging season is predicted to be sufficient to achieve a contaminant concentration equal to or somewhat greater (about 30%) than the pore water concentration of the sediment or dredged material.

The dissolved contaminants and particulate-associated contaminants in the upper portion of the CAD cell will be lost as the CAD cell water is displaced by subsequent barge discharges. Hydrodynamics modeling yielded only low velocities in the water column above the CAD cell, typically less than 0.3 fps. The velocity is sufficiently great to rapidly exchange the water above the CAD cell, typically in one to 3 hours. The velocity is sufficiently low to limit any mixing in the CAD cell water, mostly in the top foot. Therefore, only contaminants in the top foot or two of the CAD cell are subject to turbulent dispersion and exchange with the water column above the lip of the CAD cell. Contaminant losses from the CAD cell after placement of the annual lift is limited to the flux produced by diffusion from the CAD cell to the upper exchangeable water column. The annual loss of contaminants by diffusion from the lower water column is about 5 to 15% of the annual loss by expulsion of CAD cell water. Any losses by diffusion between dredging seasons would actually decrease the predicted losses during the next dredging season because the initial contaminant concentration in the CAD cell water at start of the next dredging season would be lower. Therefore, losses by diffusion from the lower water column between dredging seasons were ignored.

The predicted losses of PCBs (Aroclors 1242, 1248 and 1254) during the three years of filling the lower harbor CAD are 270 g in Year 1 (sediment composite 3), 950 g in Year 2 (sediment composite 4) and 940 g in Year 3 (sediment composite 5). The released PCBs are about 85%

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Aroclor 1242, 5% Aroclor 1248 and 10% Aroclor 1254. About 90% of the released PCBs are predicted to be dissolved. The predicted losses of copper during the three years of filling the lower harbor CAD are 1.7 kg in Year 1 (sediment composite 3), 5.9 kg in Year 2 (sediment composite 4) and 25.7 kg in Year 3 (sediment composite 5). About 50% of the released copper is predicted to be dissolved.

Long-Term Contaminant Loss from Capped CAD Cell

The contaminant fate and transport from the capped CAD cell were evaluated in two parts. The first part was evaluated during the period of dredged material consolidation using the USACE CAP model, which considers pore water advection induced by consolidation. Ninety percent of the consolidation is completed only after 30 years, but meaningful contaminant transport by pore water expulsion is limited to the first two to four years. The second part was evaluated for the long term, after significant pore water advection ceases. During the long term, contaminant transport is dominated by diffusion of contaminants from the dredged material and into the cap. Long-term contaminant fate and transport from the capped CAD cell was modeled without considering contaminant degradation or transformation using the USACE RECOVERY model.

The CAP model was run on four separate sections of the CAD cell due to differences in dredged material thickness and predicted settlement. Each section represents about one quarter of the area of the CAD cell. The first section represents the center of the CAD cell and includes the entire section of the cell that has a level bottom. The next three sections are concentric bands around the center covering the sloped area of the CAD cell. Each band has successively thinner dredged material thicknesses and smaller settlements. The CAP model results showed that the contaminants transported from the dredged material by pore water advection and diffusion would be contained in the lower foot of the cap, even in the center section, which had the largest settlement. The contaminant and sediment profiles from the end of the CAP model runs were used as the initial conditions for the long-term modeling using the RECOVERY model.

The RECOVERY model showed that most mobile of the contaminants was PCBs Aroclor 1242, followed by copper and PCBs Aroclors 1248 and 1254. Contaminant breakthrough of Aroclor 1242 and copper through the 3-foot cap is predicted to occur only after hundreds of years of diffusion. Aroclors 1248 and 1254 are predicted to breakthrough the cap only after thousands of years. The model shows that a stable 3-foot cap is highly effective in isolating the contaminated dredged material. Since about 11 ft of settlement is predicted for the center section of the CAD cell, there is a very large potential for up to 11 ft of burial over the life of the CAD cell. If this burial were considered in the long-term fate and transport modeling, the CAD cell would be effective for all contaminants for thousands of year.

Conclusions

1. A 650-foot square CAD cell excavated 47 ft below the existing sediment surface is sufficient in size to hold the sediments to be placed in the lower harbor CAD cell and to contain the collapse of the dredged material discharge during placement.
2. About 10 ft of water will be entrained in the dredged material during placement, but all of this

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water is predicted to be expelled from the consolidating dredged material during the three years of placement.

3. An additional 11 ft of settlement and pore water expulsion is predicted to occur after cap placement.
4. Dredged material resuspension will occur during placement, resulting in TSS concentrations ranging from 20 to 150 mg/L and both dissolved and particulate-associated contaminant release.
5. Dissolved contaminant concentrations in the CAD cell water will become somewhat greater (about 30% greater) than the sediment pore water being placed in the CAD cell.
6. About 2.5 kg of PCBs are predicted to be loss during dredged material placement, 90% of which would be dissolved. About 35 kg of copper are predicted to be loss during dredged material placement, 50% of which would be dissolved.
7. After capping, the contaminants expelled from the dredged material by consolidation would be contained in the lower foot of the cap.
8. Without consideration of burial, contaminant breakthrough will take hundreds to thousands of years. With burial promoted by the dredged material settlement, the transport of contaminants through the cap and burial material will take tens of thousands of years.
9. A stable 3-ft cap is highly effective in isolating the contaminated dredged material.

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